CERTIFICATION OF TRANSLATION

I, ***Sanghee Seok***, an employee of Y.P. LEE, MOCK & PARTNERS of Koryo Building, 1575-1 Seocho-dong, Seocho-gu, Seoul, Republic of Korea, hereby declare under penalty of perjury that I understand the Korean language and the English language; that I am fully capable of translating from Korean to English and vice versa; and that, to the best of my knowledge and belief, the statement in the English language in the attached translation of ***Korean Patent Application No. 10-2002-50525*** consisting of 19 pages, have the same meanings as the statements in the Korean language in the original document, a copy of which I have examined.

Signed this 19th day of September 2006

Sanghee Seok

ABSTRACT

[Abstract of the Disclosure]

A method and apparatus for automatically controlling the output power of a laser diode are provided. The method comprises (a) setting an automatic power control period for the laser diode; (b) converting an output voltage of the laser diode from an analog form to a digital form; (c) generating an error voltage between a reference voltage and an effective output voltage extracted from digital output voltages sampled during the automatic power control period; (d) performing proportional-integral processing on the error voltage to generate a compensated control voltage and generating an effective control voltage using the compensated control voltage; and (e) converting the effective control voltage from a digital form to an analog form. It is guaranteed that the output power of the laser diode is quickly stabilized at a target value even if ambient temperature of the laser diode increases.

[Representative Drawing]

FIG. 3

SPECIFICATION

[Title of the Invention]

METHOD AND APPARATUS FOR AUTOMATICALLY CONTROLLING POWER OF LASER DIODE

[Brief Description of the Drawings]

The above and other features and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a schematic block diagram of a conventional apparatus for automatically controlling the output power of a laser diode;

FIG. 2 is a block diagram showing a printer controller using an apparatus for automatically controlling the output power of a laser diode according to the present invention, and peripheral elements;

FIG. 3 is a block diagram of an apparatus for automatically controlling the output power of a laser diode according to an embodiment of the present invention;

FIG. 4 is a flowchart of a method of automatically controlling the output power of a laser diode according to an embodiment of the present invention;

FIG. 5 is a detailed flowchart of a procedure for extracting an error voltage in the method shown in FIG. 4; and

FIG. 6 is a detailed flowchart of a procedure for extracting a control voltage in the method shown in FIG. 4.

< Explanation of Reference numerals designating the Major Elements of the Drawings >

310 ... ERROR VOLTAGE GENERATION UNIT

311 ... ANALOG-TO-DIGITAL CONVERTER

312 ... EFFECTIVE OUTPUT VOLTAGE EXTRACTOR

313 ... SAMPLER

314, 326 ... COMPARATOR
315 ... ACCUMULATOR
316, 327 ... DIVIDER
317 ... MULTIPLIER
318 ... SUBTRACTOR
320 ... CONTROL VOLTAGE GENERATION UNIT
321 ... PROPORTIONAL-INTEGRAL PROCESSOR
322 ... PROPORTIONAL SECTION
323 ... INTEGRAL SECTION
324 ... ADDER
325 ... EFFECTIVE CONTROL VOLTAGE EXTRACTOR
328 ... SWITCH

[Detailed Description of the Invention]

[Object of the Invention]

[Technical Field of the Invention and Related Art prior to the Invention]

Generally, a laser printer is an apparatus for reproducing an image by writing a latent image on a photoreceptor drum according to a video signal of an input image using a laser beam emitted from a laser diode and transferring the latent image to a medium such as paper. Here, the output power characteristic of the laser diode changes depending on ambient temperature, which leads to degradation of the quality of a printed result. Therefore, many methods of compensating for varying output power according to a change in temperature have been studied.

FIG. 1 is a schematic block diagram of a conventional apparatus for automatically controlling the output power of a laser diode. The conventional apparatus includes a sensor 15, which senses the output power of a laser diode 14 positioned within a laser scanning unit (not shown); a sensed voltage input unit 16, which converts the sensed output power of the laser diode 14 to an appropriate form and inputs the converted result to a printer controller 11; and an automatic power controller 13, which controls the output power of the laser diode 14 using an ON/OFF

method under the authorization of the printer controller 11 receiving the sensed voltage from the sensed voltage input unit 16.

In such a conventional apparatus for automatically controlling the output power of a laser diode, since members such as the printer controller, the automatic power controller, and the sensed voltage input unit exist as separate blocks, a circuit occupies a wide area when hardware is implemented. Accordingly, it is difficult to manufacture a miniaturized, light, and inexpensive product. Moreover, since the automatic power controller is realized as an analog circuit, it has low flexibility for feedback control. In addition, since in the ON/OFF method, the amount of control performed until the output power of the laser diode has a target value largely varies in a range of 0-100%, the accuracy of control is low, and the controlled output power of the laser diode continuously fluctuates near the target value.

[Technical Goal of the Invention]

The present invention provides a method of automatically controlling the output power of a laser diode to minutely approach a target value using proportional-integral control.

The present invention also provides an apparatus for automatically controlling the output power of a laser diode.

The present invention also provides a laser printer controller including the apparatus for automatically controlling the output power of a laser diode therewithin.

[Structure and Operation of the Invention]

According to an aspect of the present invention, there is provided a method of automatically controlling an output power of a laser diode, the method comprising: (a) setting an automatic power control period for the laser diode; (b) converting an output voltage of the laser diode from an analog form to a digital form; (c) generating an error voltage between a reference voltage and an effective output voltage extracted from digital output voltages sampled during the automatic power control period; (d) performing proportional-integral processing on the error voltage to generate a

compensated control voltage and generating an effective control voltage using the compensated control voltage; and (e) converting the effective control voltage from a digital form to an analog form.

According to another aspect of the present invention, there is provided an apparatus for automatically controlling an output power of a laser diode, the apparatus comprising: an error voltage generation unit, which generates an error voltage between an output voltage of the laser diode, which is sampled during an automatic power control period, and a reference voltage; and a control voltage generation unit, which performs proportional-integral processing on the error voltage provided from the error voltage generation unit to generate an effective control voltage.

Preferably, the error voltage generation unit comprises: an analog-to-digital converter, which converts the output voltage of the laser diode from an analog form to a digital form; an effective output voltage extractor, which extracts an effective output voltage from the digital output voltage provided from the analog-to-digital converter; and a subtractor, which subtracts a reference voltage from the effective output voltage provided from the effective output voltage extractor to generate the error voltage.

Preferably, the effective output voltage extractor comprises: a sampler, which samples the digital output voltage provided from the analog-to-digital converter during the automatic power control period; a comparator, which compares the sampled output voltage with a first maximum and a first minimum, determines whether the sampled output voltage exists within an effective range defined by the first maximum and minimum, and extracts the effective output voltage within the effective range; an accumulator, which accumulates the effective output voltage extracted by the comparator; and a divider, which divides the accumulated effective output voltage by the number of accumulations to obtain an average effective output voltage.

According to still another aspect of the present invention, there is provided a laser printer controller comprising: an engine processor module, which controls the entire operation of a printer engine; and an automatic power control module for a laser diode, which automatically controls an output power of the laser diode positioned within a laser scanning unit by sampling an effective output voltage from the output power of

the laser diode during a predetermined automatic power control period and performing proportional-integral processing on the effective output voltage, the laser printer controller being structured in a single integrated circuit.

Preferred embodiments of the present invention will now be described with reference to the attached drawings.

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the attached drawings.

FIG. 2 is a block diagram showing a printer controller 21 including an automatic power control module 23 for a laser diode according to the present invention, and peripheral elements. The printer controller 21 is an integrated circuit including an engine processor module 22 and the automatic power control module 23. The engine processor module 22 controls the entire operation of a printer engine 24. The automatic power control module 23 automatically controls the output power of a laser diode 25, which is sensed by a sensor 26, to minutely approach a target value using proportional-integral control. The laser diode 25 is included within a laser scanning unit (not shown).

FIG. 3 is a block diagram of the automatic power control module 23 shown in FIG. 2 according to an embodiment of the present invention. The automatic power control module 23 includes an error voltage generation unit 310 and a control voltage generation unit 320. The error voltage generation unit 310 includes an analog-to-digital converter 311, an effective output voltage extractor 312, and a subtractor 318. The effective output voltage extractor 312 includes a sampler 313, a first comparator 314, an accumulator 315, and a first divider 316. The control voltage generation unit 320 includes a proportional-integral processor 321, an effective control voltage extractor 325, and a digital-to-analog converter 329. The proportional-integral processor 321 includes a proportional section 322, an integral section, and an adder 324. The effective control voltage extractor 325 includes a second comparator 326. In the meantime, in order to simplify decimal point calculation, the effective output voltage extractor 312 further includes a multiplier 317, and the effective control voltage extractor 325 further includes a second divider 327.

The error voltage generation unit 310 generates an error voltage between an output voltage of the laser diode 25 (FIG. 2), which is extracted for the duration of automatic power control set to have a predetermined period, and a reference voltage.

More specifically, the analog-to-digital converter 311 converts the voltage of the output power of the laser diode 25 to a digital output voltage. The sampler 313 samples the digital output voltage received from the analog-to-digital converter 311 during the automatic power control period. In another embodiment, the sampler 313 can set an automatic power control period and control the analog-to-digital converter 311 to perform conversion during only the automatic power control period. In addition, the sampler 313 can set the number of samplings during the automatic power control period. In this case, the sampler 313 performs the set number of samplings on the digital output voltage received from the analog-to-digital converter 311.

The first comparator 314 previously sets a first maximum and a first minimum to define an effective range of the digital output voltage of the laser diode 25, compares the first maximum and the first minimum with the sampled digital output voltage received from the sampler 313, and determines whether the sampled digital output voltage exists within the effective range. As the result of determination, the first comparator 314 outputs only an effective output voltage within the effective range to the accumulator 315 and increases the number of accumulations C_s by 1 whenever outputting the effective output voltage to the accumulator 315. The first maximum and the first minimum are set in order to take only normal components from the output power of the laser diode 25 except for error components and preferably obtained through experiments.

The accumulator 315 accumulates the effective output voltage provided from the first comparator 314. The first divider 316 divides the accumulated result output from the accumulator 315 by the number of accumulations C_s to calculate an average effective output voltage. The multiplier 317 multiplies the average effective output voltage received from the first divider 316 by a predetermined multiplication constant K_m in order to simplify decimal point calculation in the proportional-integral processor 321 and outputs the multiplied result to the subtractor 318. The subtractor 318 subtracts

the reference voltage, i.e., a control target value for the laser diode, from the multiplied result received from the multiplier 317 to generate an error voltage.

In the meantime, the control voltage generation unit 320 performs proportional-integral processing on the error voltage received from the error voltage generation unit 310 to generate a compensated control voltage and applies the compensated control voltage to the laser diode 25.

More specifically, in the proportional-integral processor 321, the proportional section 322 multiplies the error voltage by a proportional constant K_p to generate a proportional term; the integral section 323 accumulates the error voltage and multiplies the accumulated error voltage by an integral constant K_i to generate an integral term; and the adder 324 adds up the proportion term and the integral term and outputs the result of addition. The proportional constant K_p and the integral constant K_i are optimal values selected from the results of actual control using a cut-and-try method. The proportional-integral processor 321 can add a single sign bit to the output of the subtractor 318 in order to simplify proportional-integral processing since a negative value may be generated as the result of the subtraction of the subtractor 318.

In the effective control voltage extractor 325, the second comparator 326 previously sets a second maximum and a second minimum which define an effective range of a control voltage for the laser diode 25, compares the proportional-integral processed error voltage, i.e., a control voltage, received from the proportional-integral processor 321 with the second maximum and minimum, and determines whether the control voltage exists within the effective range. As the result of determination, only an effective control voltage within the effective range is output to the second divider 327. When the control voltage is beyond the effective range, the control voltage is ignored, and the second comparator 326 waits until another control voltage obtained during the next automatic power control period is received from the proportional-integral processor 321.

The second divider 327 divides the effective control voltage received from the second comparator 326 by a division constant K_d and outputs the divided effective control voltage to the switch 328. Here, it is preferable that the division constant K_d is

the same as the multiplication constant K_m. The division constant K_d and the multiplication constant K_m can be obtained through experiments.

The switch 328 switches the output of the effective control voltage provided from the second divider 327. When different types of automatic power control modules 23, such as one using an ON/OFF method and one using a proportional-integral control method, are implemented in a single circuit, the switch 328 is operated according to a user's selection so as to provide the effective control voltage from the second divider 327 to the digital-to-analog converter 329. The digital-to-analog converter 329 converts the effective control voltage provided from the switch 328 to an analog form and applies the converted effective control voltage to the laser diode 25.

FIG. 4 is a flowchart of a method of automatically controlling the output power of a laser diode according to an embodiment of the present invention. Referring to FIG. 4, an automatic power control period for the laser diode 25 is set in step 41. The output voltage of the laser diode 25 is converted from an analog form to a digital form in step 43.

In step 45, the digital output voltage of the laser diode 25 is sampled during the automatic power control period, and an error voltage between an effective output voltage extracted from sampled digital output voltages and a reference voltage is generated. Step 45 will be described in detail with reference to FIG. 5.

Referring to FIG. 5, the number of samplings or a sampling rate during the automatic power control period set in step 41 is set in step 51. Preferably, step 51 is selectively performed when necessary.

The set number of samplings is performed on the digital output voltage obtained in step 43 during the automatic power control period in step 52. Each sampled digital output voltage is compared with a first maximum and a first minimum, which are the upper and lower limits of an effective range previously set, and a digital output voltage within the effective range is extracted as an effective output voltage, in step 53.

The effective output voltage is accumulated in step 54. An average effective output voltage is calculated in step 55. The error voltage between the average effective output voltage and a predetermined reference voltage is generated in step 57.

Here, in order to simplify decimal point calculation, the average effective output voltage can be multiplied by a predetermined multiplication constant K_m in step 56.

Referring back to FIG. 4, in step 47, proportional-integral processing is performed on the error voltage generated in step 45 to generate a compensated control voltage, and an effective control voltage is generated from the compensated control voltage. Step 47 will be described in detail with reference to FIG. 6.

Referring to FIG. 6, proportional-integral processing is performed on the error voltage generated in step 45 using a proportional constant K_p and an integral constant K_I to generate a compensated control voltage in step 61.

The compensated control voltage is compared with a second maximum and a second minimum, which are the upper and lower limit of a predetermined effective range, to determine whether the compensated control voltage exists within the effective range in step 62. If it is determined that the compensated control voltage does not exist within the effective range, the method returns back to step 41 to be performed with respect to the next automatic power control period.

Conversely, if it is determined that the compensated control voltage exists within the effective range, the compensated control voltage is generated as an effective control voltage in step 64. In the meantime, in the case where the multiplication constant K_m is used during the generation of the error voltage, the effective control voltage is divided by a division constant K_d in step 65.

Referring back to FIG. 4 again, the effective control voltage is converted from a digital form to an analog form and then applied to the laser diode 25 in step 49.

[Effect of the Invention]

As described above, according to the present invention, among digital output voltages of a laser diode which are sampled during a predetermined automatic power control period, a digital output voltage within an effective range is extracted, and an error voltage between the extracted digital output voltage and a reference voltage is obtained. Next, among compensated control voltages obtained by performing proportional-integral processing on the error voltage, an effective control voltage within

an effective range is extracted and used to control the output power of the laser diode. Therefore, the present invention guarantees that the output power of the laser diode is quickly stabilized at a target value even if ambient temperature of the laser diode increases. In addition, according to the present invention, an automatic power control module for a laser diode can be realized in a digital form and integrated into a printer controller, miniaturized, light, and inexpensive laser printers can be manufactured.

While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. The preferred embodiments should be considered in descriptive sense only and not for purposes of limitation. Therefore, the scope of the invention is defined not by the detailed description of the invention but by the appended claims, and all differences within the scope will be construed as being included in the present invention.

What is claimed is:

4. A method of automatically controlling an output power of a laser diode, the method comprising:

(a) setting an automatic power control period for the laser diode;

(b) converting an output voltage of the laser diode from an analog form to a digital form;

(c) generating an error voltage between a reference voltage and an effective output voltage extracted by comparing a digital output voltage sampled during the automatic power control period with a first effective period;

(d) performing proportional-integral processing on the error voltage to generate a compensated control voltage

(e) generating an effective control voltage comparing the compensated control voltage with a second effective period; and

(f) converting the effective control voltage from a digital form to an analog form.

5. The method of claim 4, wherein step (c) comprises:

(c1) sampling the digital output voltage of the laser diode during the automatic power control period;

(c2) extracting the sampled digital output voltage that exists within a range between a first maximum and a first minimum as the effective output voltage;

(c3) calculating an average effective output voltage; and

(c4) generating the error voltage between the average effective output voltage and the reference voltage.

6. The method of claim 4, wherein step (e) comprises:

(e1) generating the compensated control voltage that exists within a range between a second maximum and a second minimum as the effective control voltage.

7. An apparatus for automatically controlling an output power of a laser diode, the apparatus comprising:

an error voltage generation unit, which generates an error voltage between a reference voltage and an effective output voltage extracted by comparing the digital output voltage of the laser diode, which is sampled during an automatic power control period, with a first effective period; and

a control voltage generation unit, which performs proportional-integral processing on the error voltage, and converts the effective control voltage generated by comparing the compensated control voltage with the second effective period, from analog form to digital form.

8. The apparatus of claim 7, wherein the error voltage generation unit comprises:

an analog-to-digital converter, which converts the output voltage of the laser diode from an analog form to a digital form;

an effective output voltage extractor, which extracts an effective output voltage from the digital output voltage provided from the analog-to-digital converter; and

a subtractor, which subtracts a reference voltage from the effective output voltage provided from the effective output voltage extractor to generate the error voltage.

9. The apparatus of claim 8, wherein the effective output voltage extractor comprises:

a sampler, which samples the digital output voltage provided from the analog-to-digital converter during the automatic power control period;

a comparator, which compares the sampled output voltage with a first maximum and a first minimum, determines whether the sampled output voltage exists within an effective range defined by the first maximum and minimum, and extracts the effective output voltage within the effective range;

an accumulator, which accumulates the effective output voltage extracted by the comparator; and

a divider, which divides the accumulated effective output voltage by the number of accumulations to obtain an average effective output voltage.

10. The apparatus of claim 8, wherein the effective output voltage extractor comprises:

a sampler, which controls the analog-to-digital converter to perform conversion during only the automatic power control period;

a comparator, which compares the output voltage provided from the sampler with a first maximum and a first minimum, determines whether the sampled output voltage exists within an effective range defined by the first maximum and minimum, and extracts the effective output voltage within the effective range;

an accumulator, which accumulates the effective output voltage extracted by the comparator; and

a divider, which divides the accumulated effective output voltage by the number of accumulations to obtain an average effective output voltage.

11. The apparatus of claim 8, further comprising a multiplier, which multiplies an output of the divider by a predetermined multiplication constant.

12. The apparatus of claim 7, wherein the control voltage generation unit comprises:

a proportional-integral processor, which performs proportional-integral processing on the error voltage provided from the error voltage generation unit using a predetermined proportional constant and a predetermined integral constant to generate a compensated control voltage;

an effective control voltage extractor, which extracts the effective control voltage from the compensated control voltage provided from the proportional-integral processor; and

a digital-to-analog converter, which converts the effective control voltage provided from the effective control voltage extractor to an analog form and applying the effective control voltage in analog form to the laser diode.

13. The apparatus of claim 12, wherein the effective control voltage extractor compares the compensated control voltage with a second maximum and a second minimum, which defines an effective range, in order to determine whether the compensated control voltage exists within the effective range, and extracts the effective control voltage within the effective range.

14. The apparatus of claim 7, further comprising a divider, which divides the effective control voltage provided from the effective control voltage extractor by a predetermined division constant.

15. A laser printer controller comprising:

an engine processor module, which controls the entire operation of a printer engine; and

an automatic power control module for a laser diode, which automatically controls an output power of the laser diode positioned within a laser scanning unit by sampling an effective output voltage from the output power of the laser diode during a predetermined automatic power control period and performing proportional-integral processing on the effective output voltage,

the laser printer controller being structured in a single integrated circuit.

FIG. 1 (PRIOR ART)

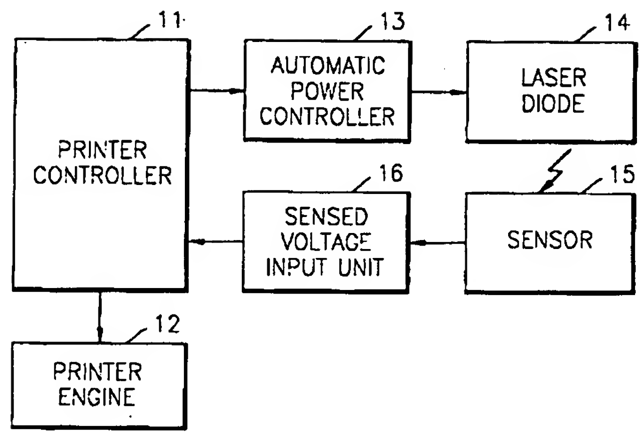


FIG. 2

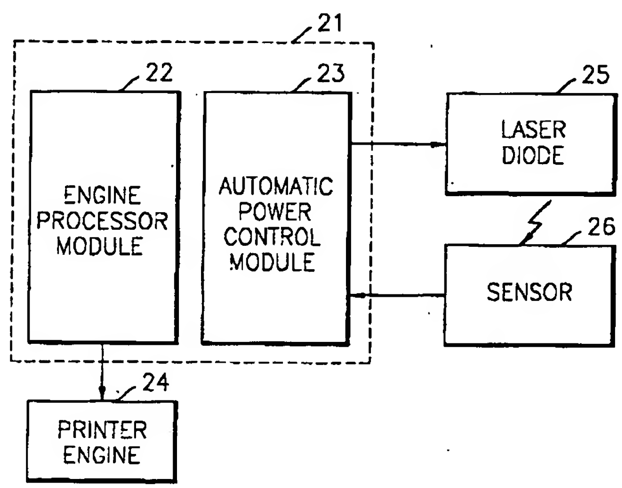
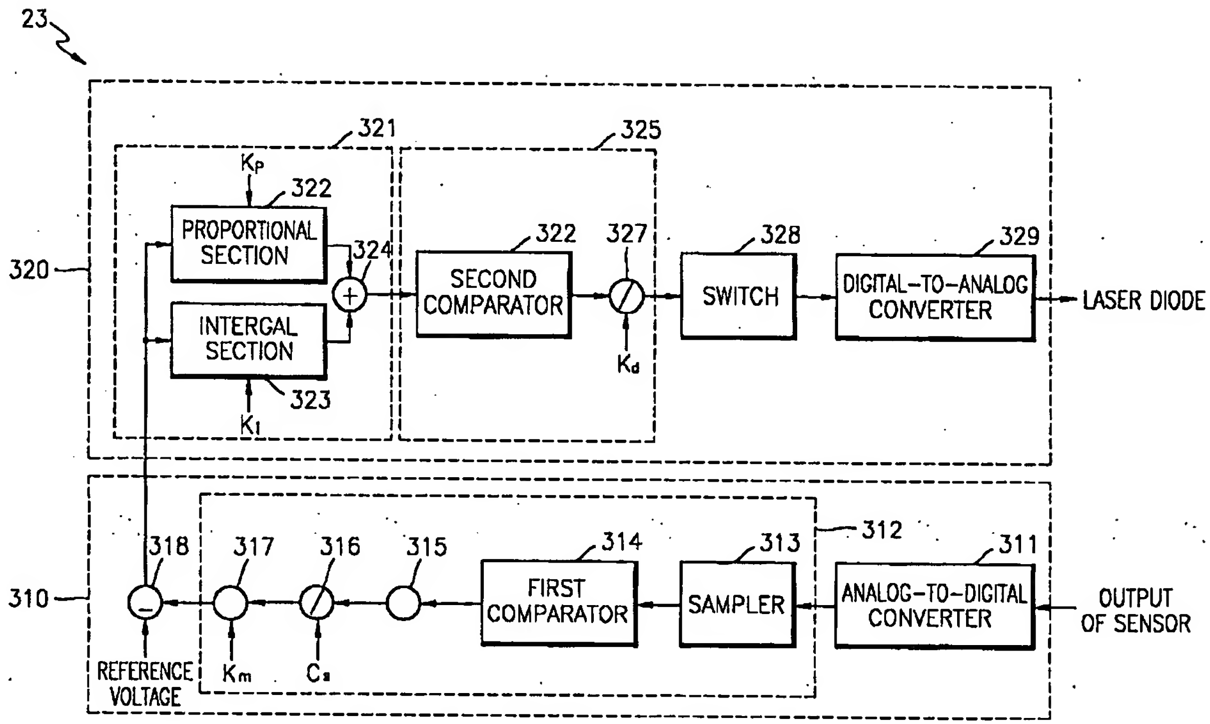


FIG. 3



23
320
321
325
K_P
322
PROPORTIONAL SECTION
324
INTERGAL SECTION
323
K_I
322
SECOND COMPARATOR
327
K_d
328
SWITCH
329
DIGITAL-TO-ANALOG CONVERTER
LASER DIODE
310
318
317
316
315
314
313
312
311
REFERENCE VOLTAGE
K_m
C_a
FIRST COMPARATOR
SAMPLER
ANALOG-TO-DIGITAL CONVERTER
OUTPUT OF SENSOR

FIG. 5

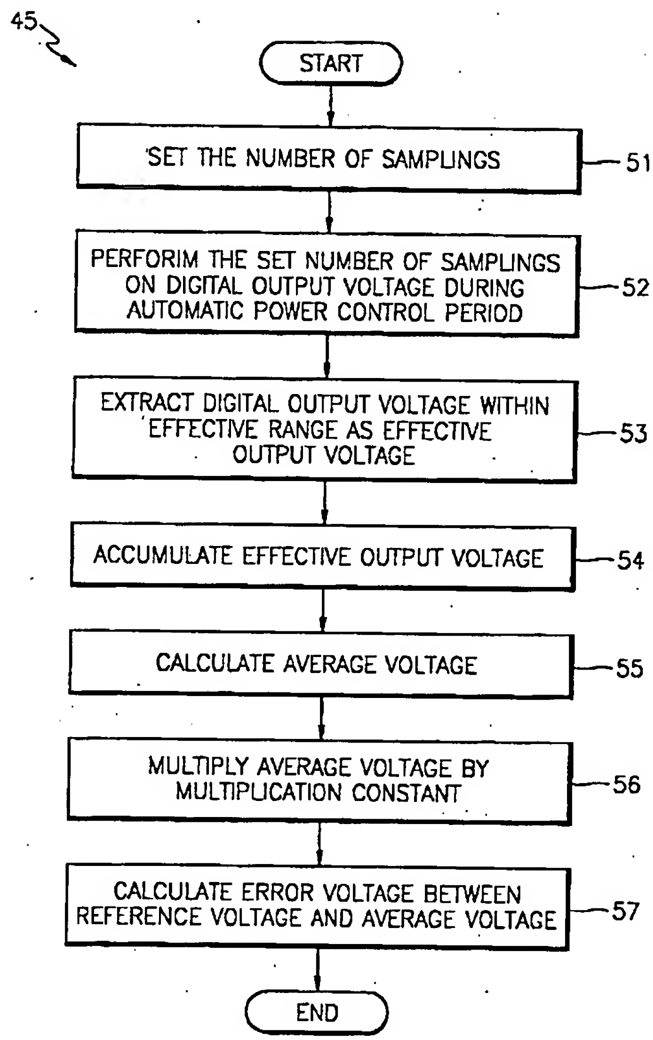
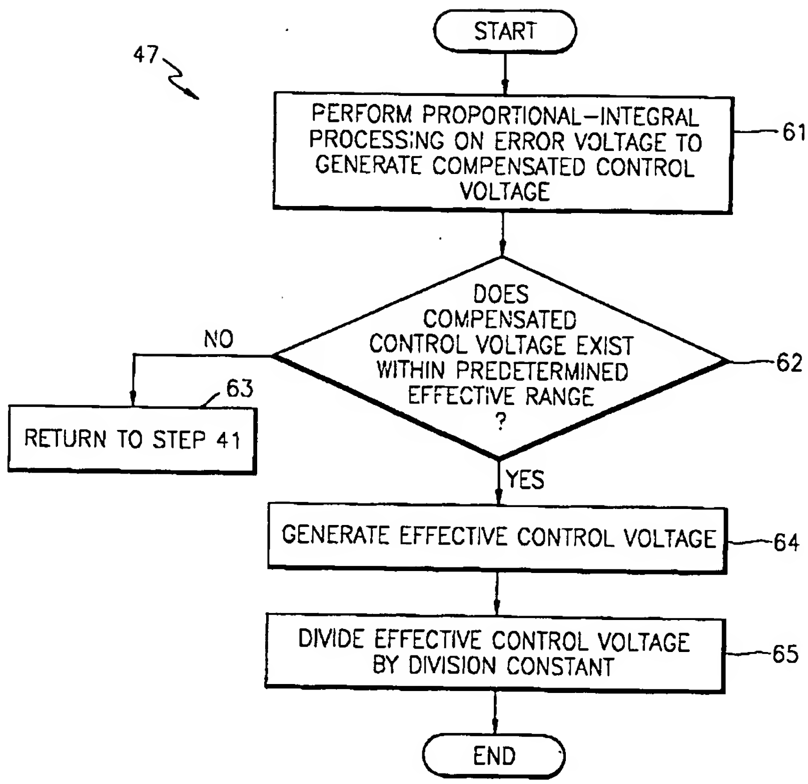

45
START
SET THE NUMBER OF SAMPLINGS
51
PERFORIM THE SET NUMBER OF SAMPLINGS ON DIGITAL OUTPUT VOLTAGE DURING AUTOMATIC POWER CONTROL PERIOD
52
EXTRACT DIGITAL OUTPUT VOLTAGE WITHIN EFFECTIVE RANGE AS EFFECTIVE OUTPUT VOLTAGE
53
ACCUMULATE EFFECTIVE OUTPUT VOLTAGE
54
CALCULATE AVERAGE VOLTAGE
55
MULTIPLY AVERAGE VOLTAGE BY MULTIPLICATION CONSTANT
56
CALCULATE ERROR VOLTAGE BETWEEN REFERENCE VOLTAGE AND AVERAGE VOLTAGE
57
END

FIG. 6


47
START
PERFORM PROPORTIONAL–INTEGRAL PROCESSING ON ERROR VOLTAGE TO GENERATE COMPENSATED CONTROL VOLTAGE
61
DOES COMPENSATED CONTROL VOLTAGE EXIST WITHIN PREDETERMINED EFFECTIVE RANGE ?
62
NO
63
RETURN TO STEP 41
YES
GENERATE EFFECTIVE CONTROL VOLTAGE
64
DIVIDE EFFECTIVE CONTROL VOLTAGE BY DIVISION CONSTANT
65
END